# Soil Moisture Statistics: Sampling, Averaging and Interpretation

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# Main Topics

- How many samples do I need?
- To average or not to average
- Spatial dependence and co-dependence

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# Soil moisture is variable so we need statistics

- Mean – the expected value of the variable (soil water content)
- Standard deviation – a measure of dispersion about the mean. There is a 68% chance that a given measurement is within ±1 std. dev. of the mean; a 95% chance of it being within ±2 std. dev.

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# Example

- We measure a water content of 27%
- We know (or assume) the water content standard deviation is 3%
- The mean or expected value of the soil water content is therefore likely (95% chance) between 21 and 33%

# What if we need a more accurate value?

- Sample multiple values of water content
- Compute the average water content

$$s_m = \frac{s}{\sqrt{n}}$$

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# Another example

- 100 samples give an average of 28%
- Std. dev. of mean = 3/10 = 0.3%
- The mean or expected value of the soil water content is therefore likely (95% chance) between 27.4 and 28.6%

# How many samples do I need?

- What accuracy is needed?
- What is the std. dev.
- Accuracy = ± 2 std. dev. of mean

$$n = \left(\frac{s}{s_m}\right)^2 = \left(\frac{2s}{e}\right)^2$$

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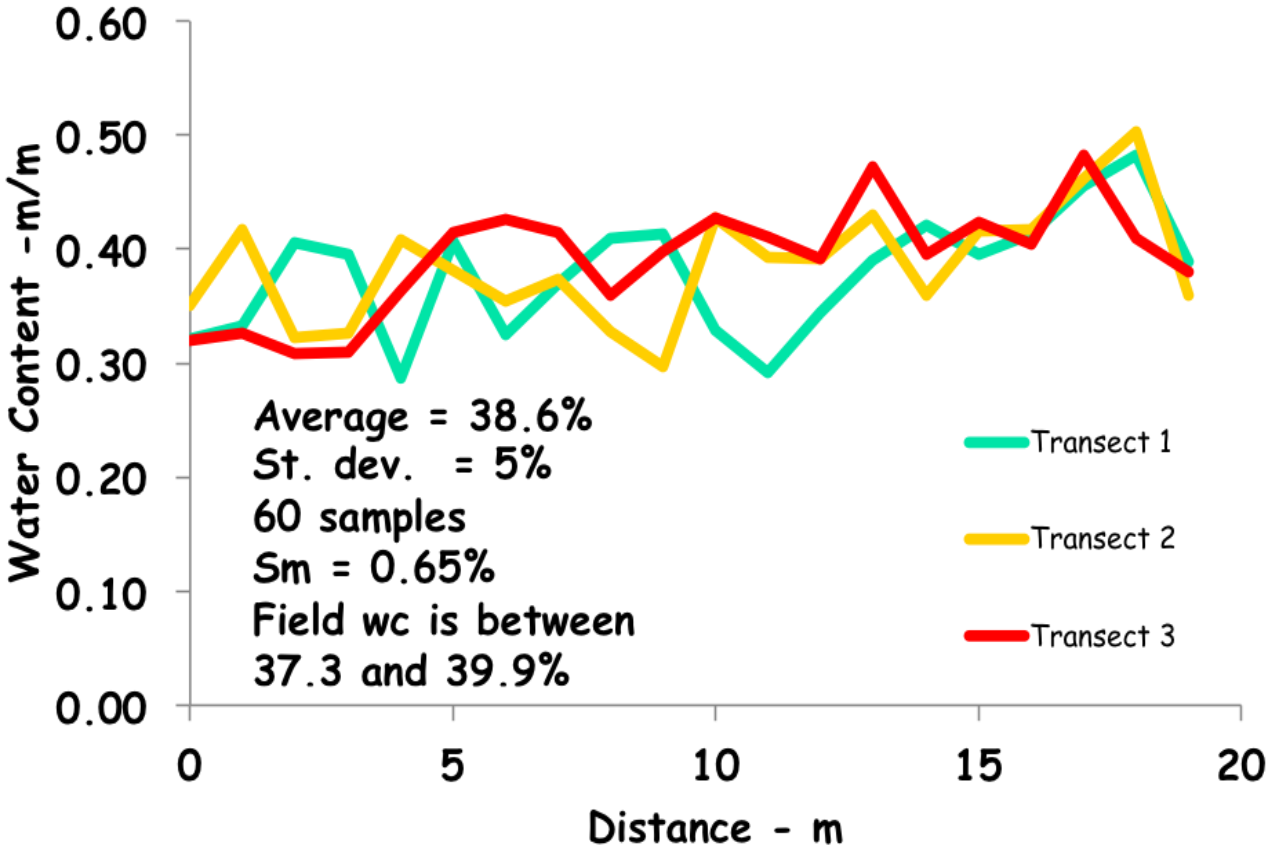
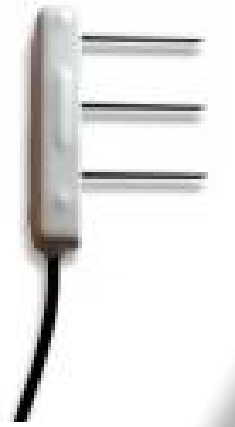
# Number of samples - calculation

- How many samples would we need to know water content within 1%?
- Std. dev. is 3%, $\varepsilon$ = 1%,
  $n = (2x3/1)^2 = 36$

# Field data – 3 transects, 1 m spacing

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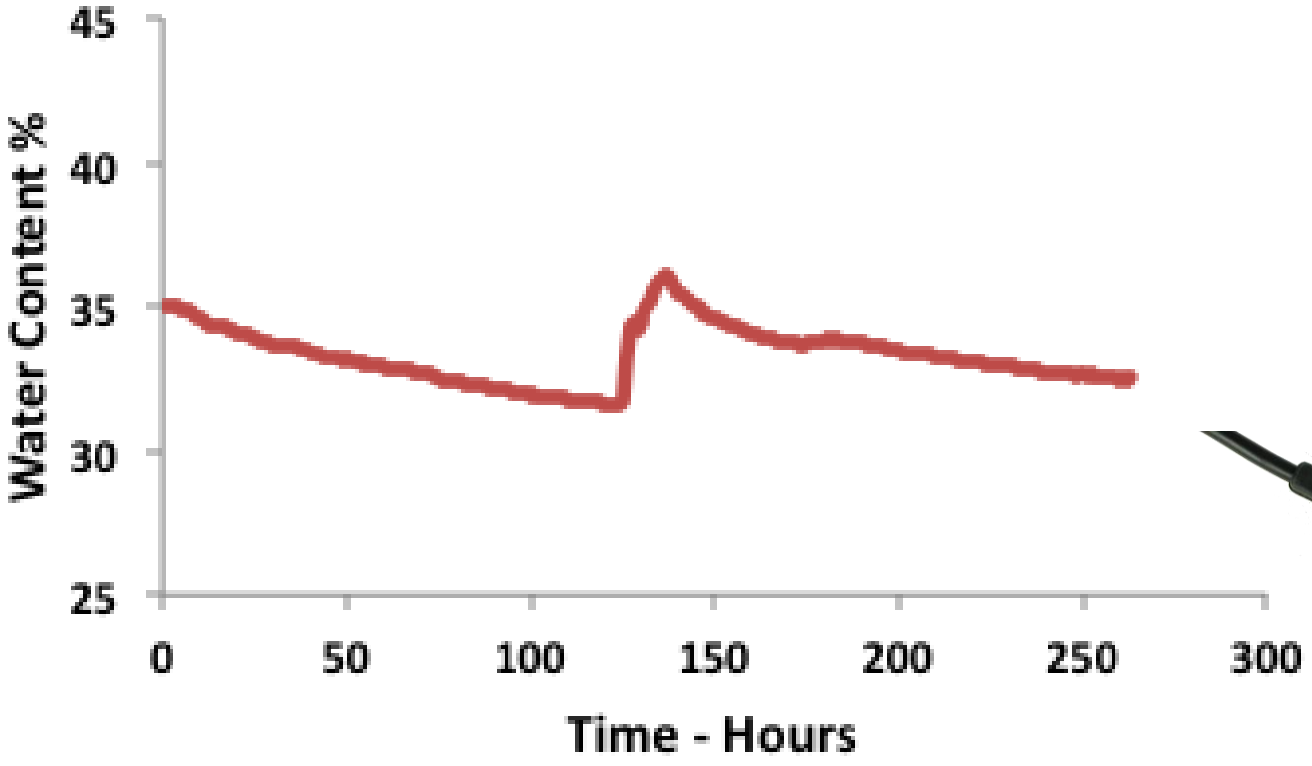
# Drydown/wetup of a single, installed sensor





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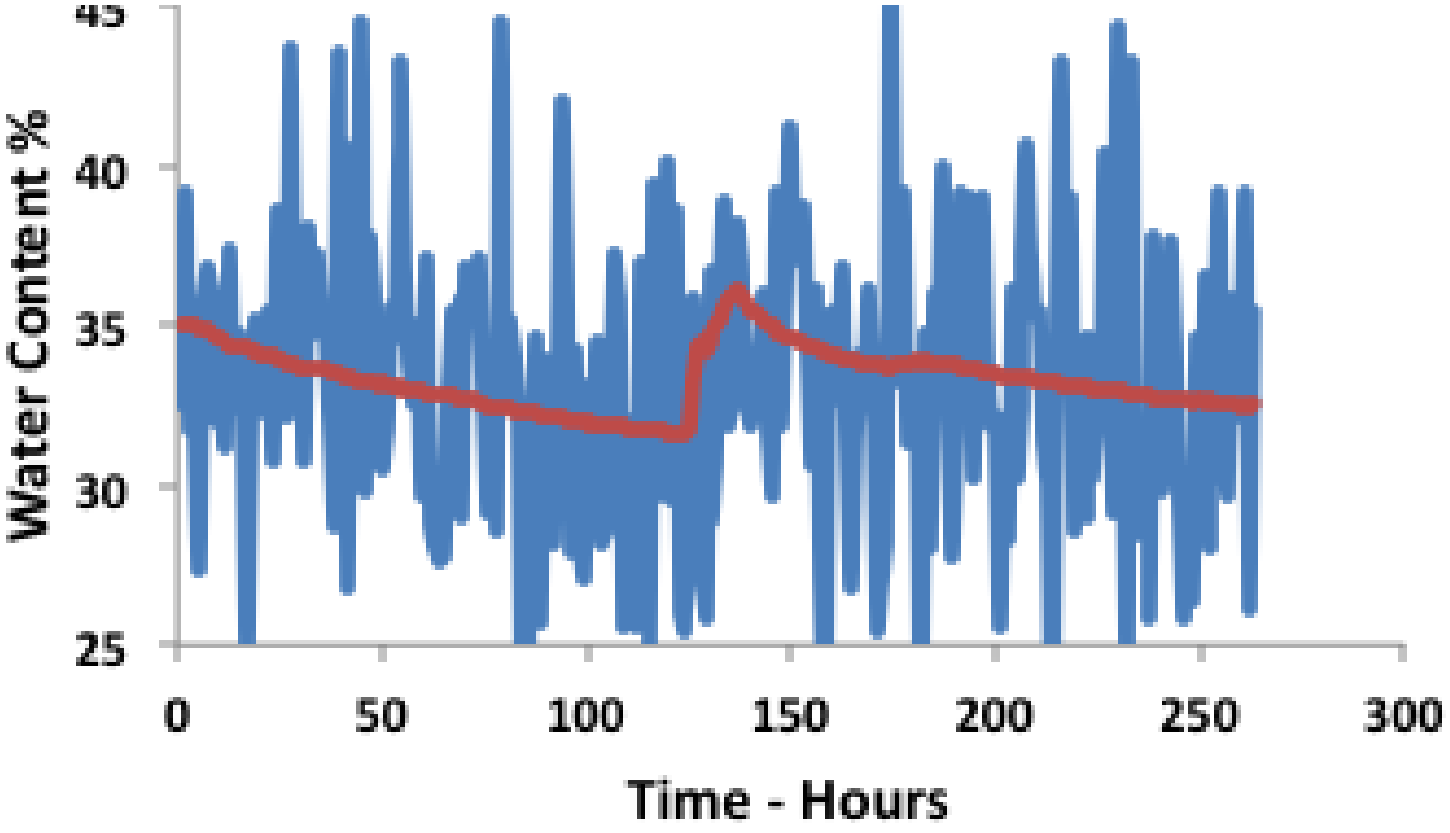
# One sample per hour

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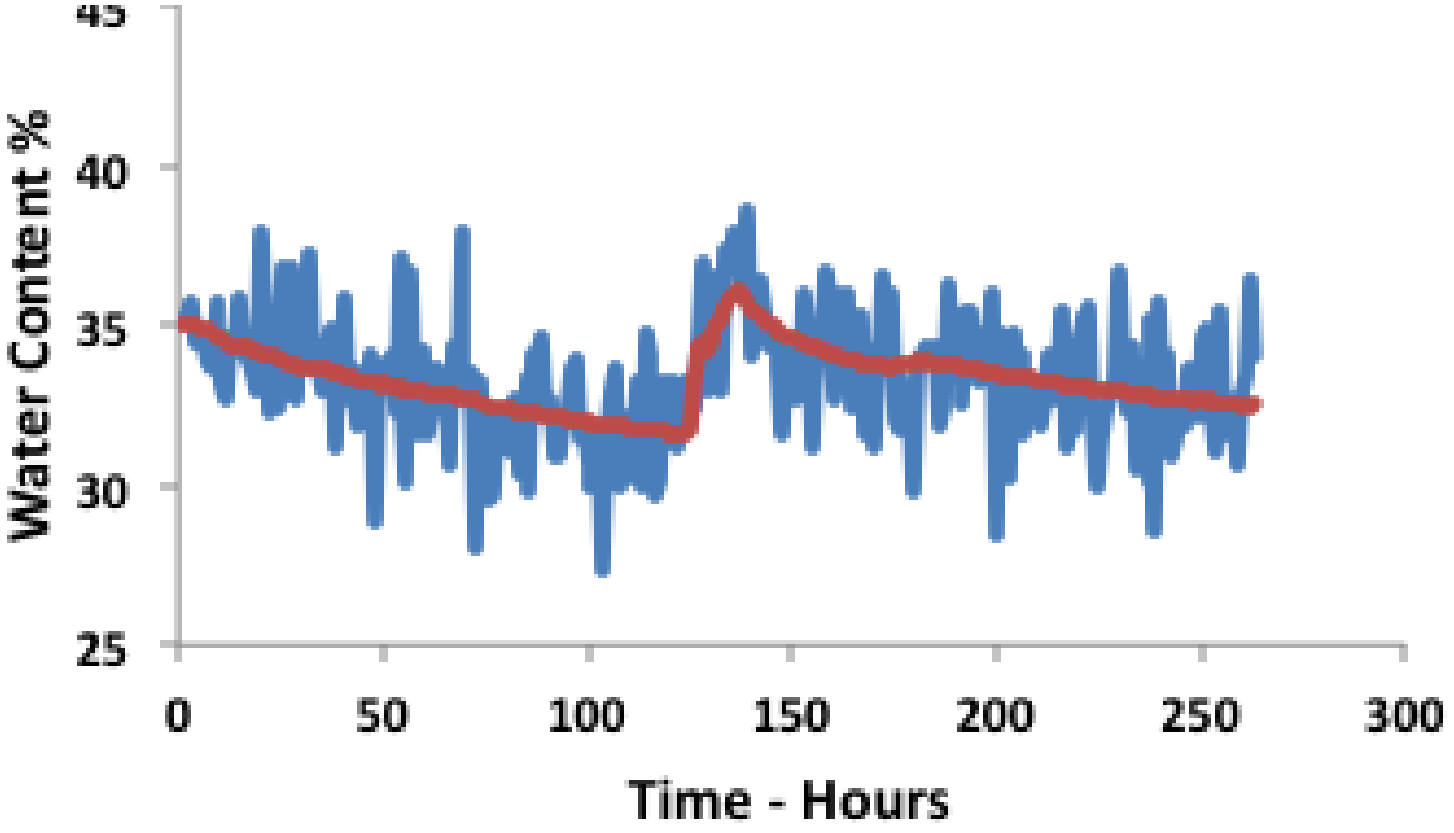
# 10 samples per hour

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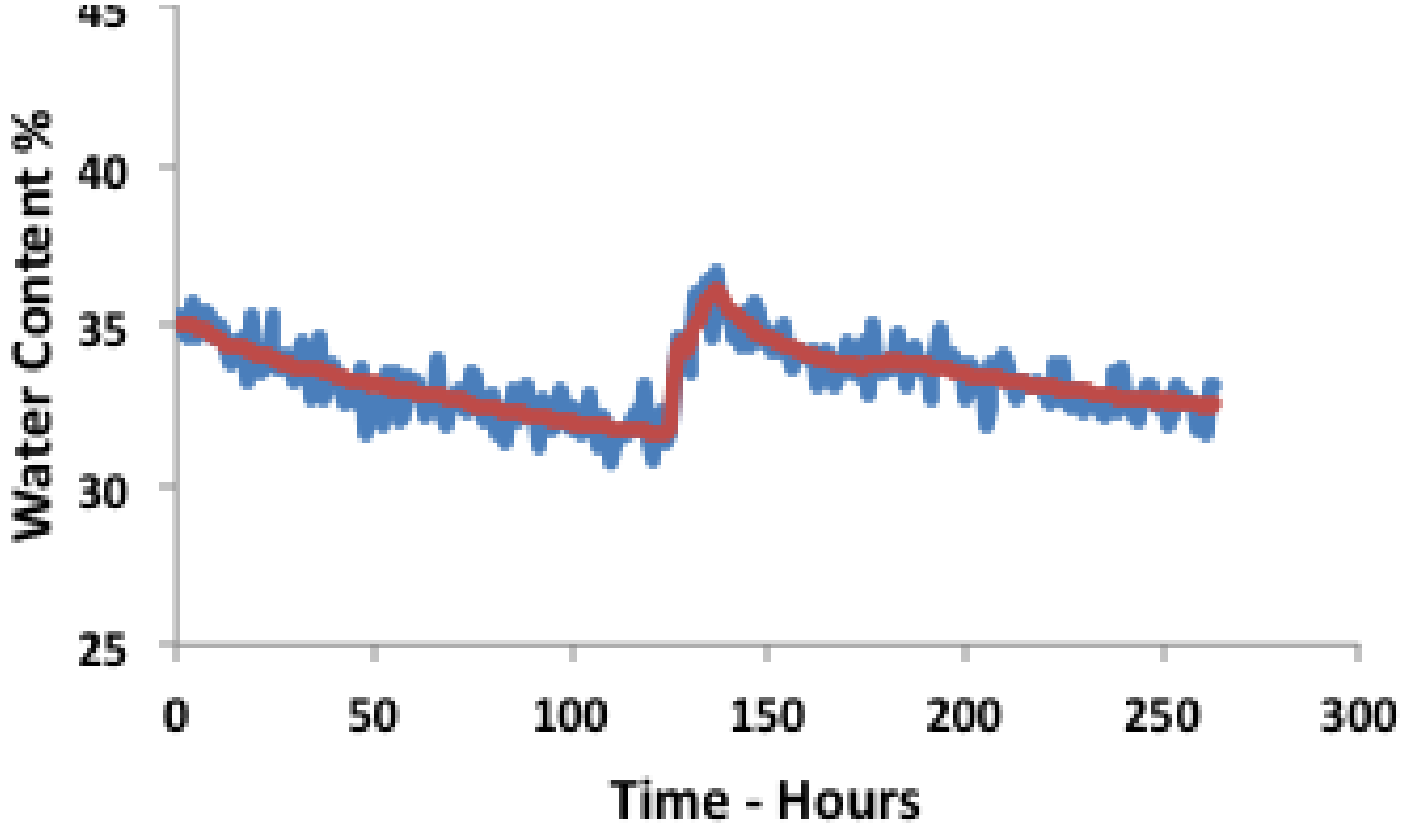
# 100 samples per hour

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# Points to remember

- Soil water content varies from place to place
- We usually need to average several measurements to know what the water content is – and then we don't know it very well
- We usually can't afford enough sensors to "know" what the water content is

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# More points to remember

- But - for many purposes you just need to know if water content changed, not what it is, exactly.
- You can get around many effects of spatial variability by monitoring *in situ*

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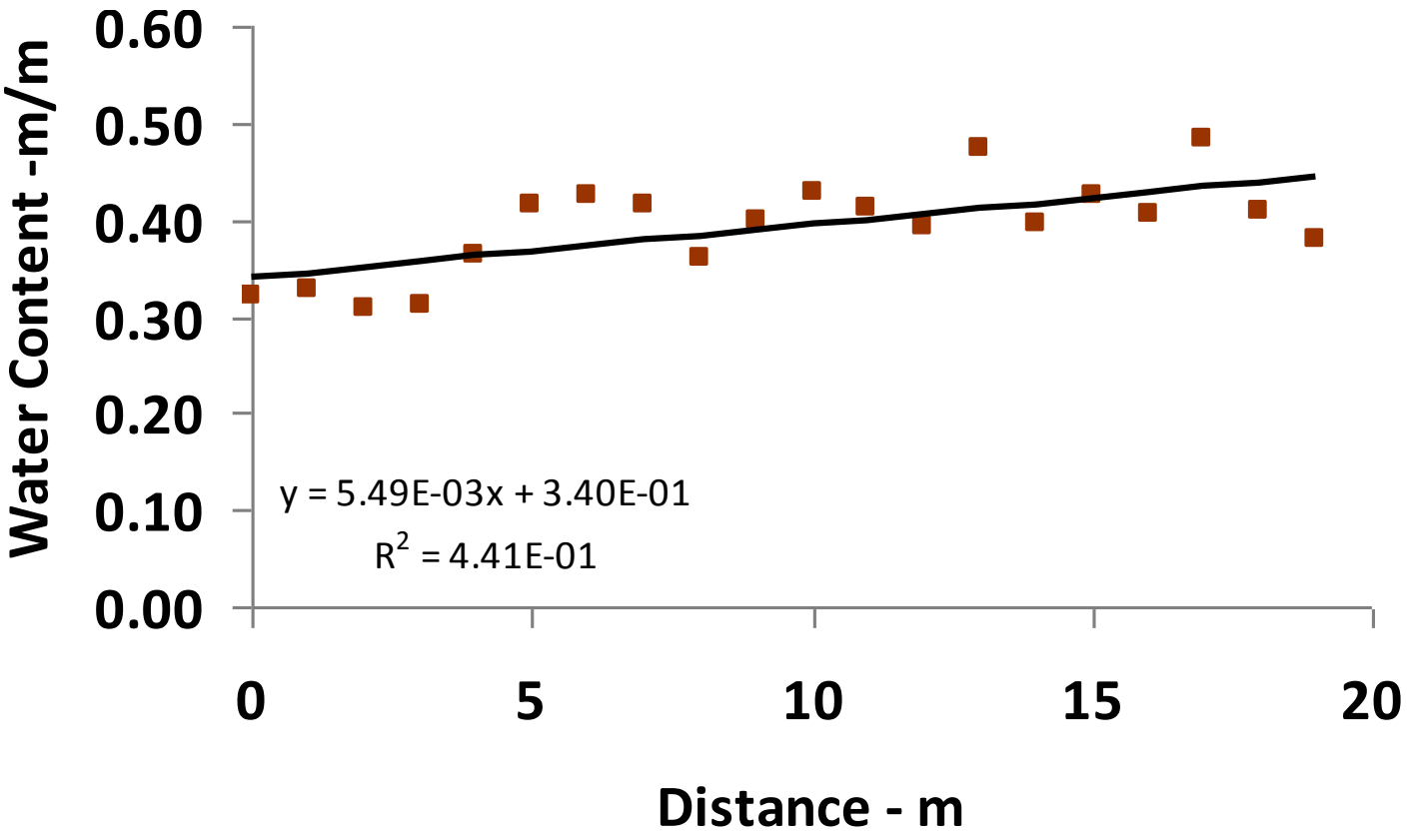
# Systematic and Random Variation in Soil Moisture




Variance
44% model
56% random

Std dev 5%
$s_{yx}$ 3.5%

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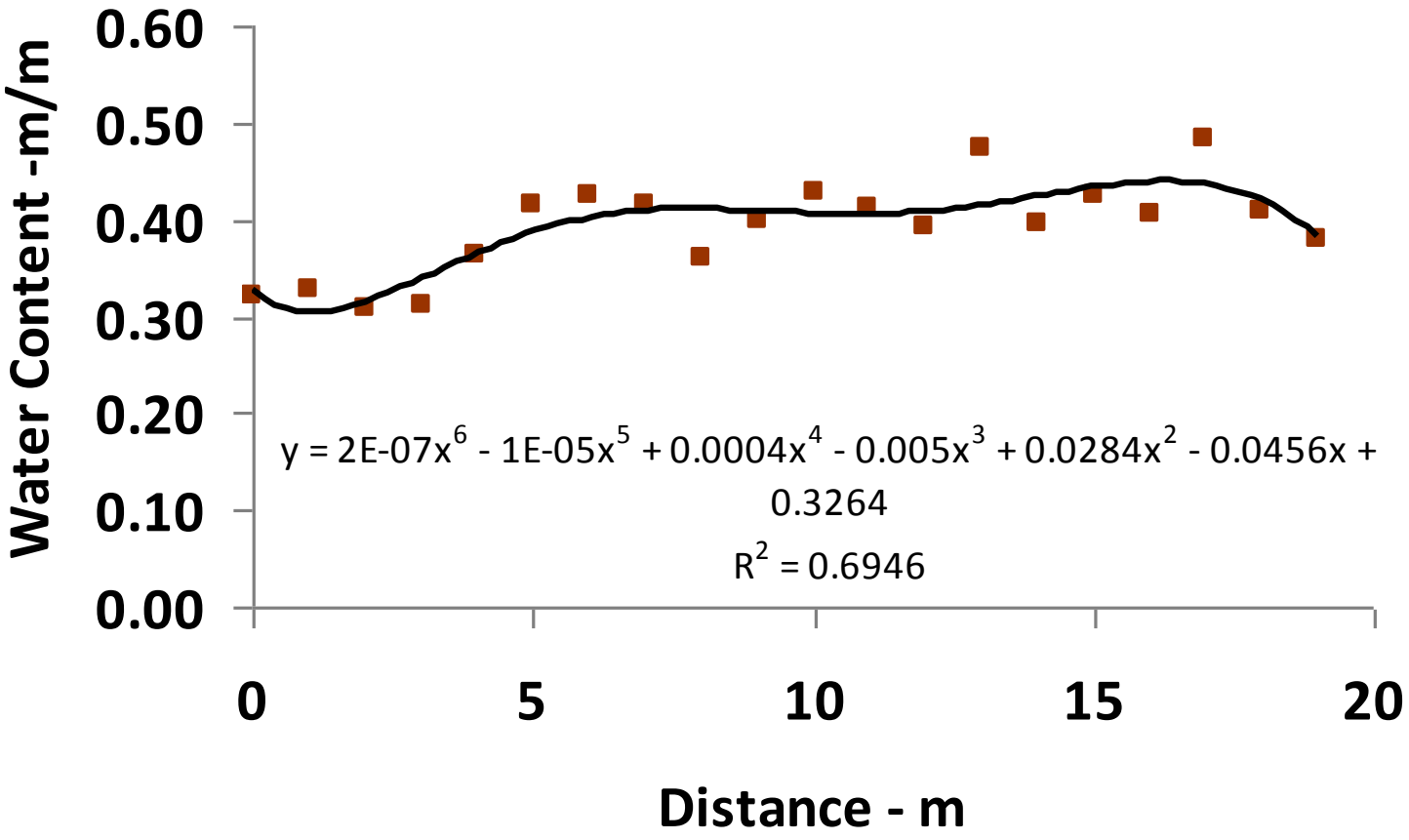
# Maybe there is even more structure to be modeled--




Variance
Model 69%
Random 31%

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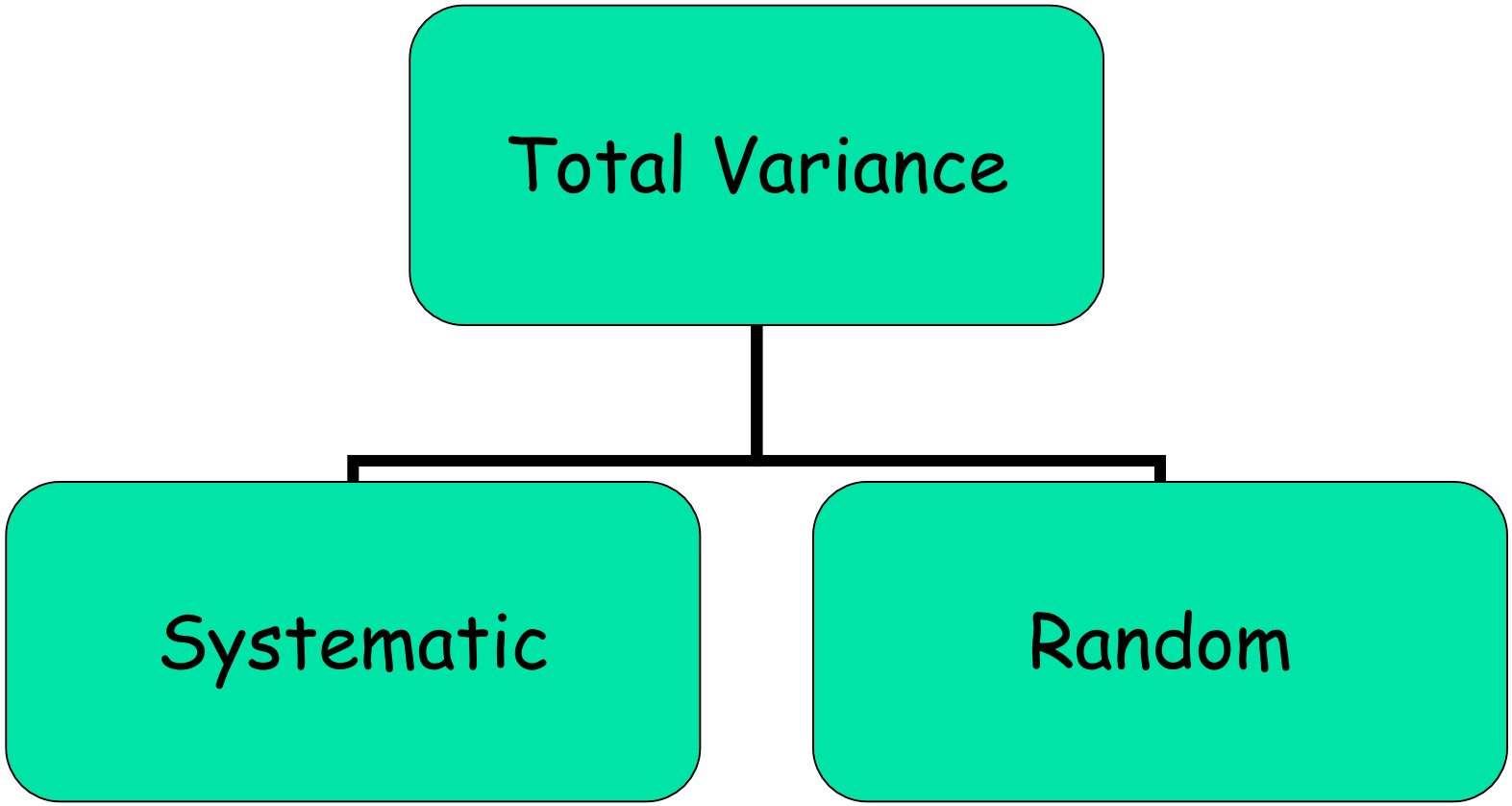
# Total variance is the sum two components

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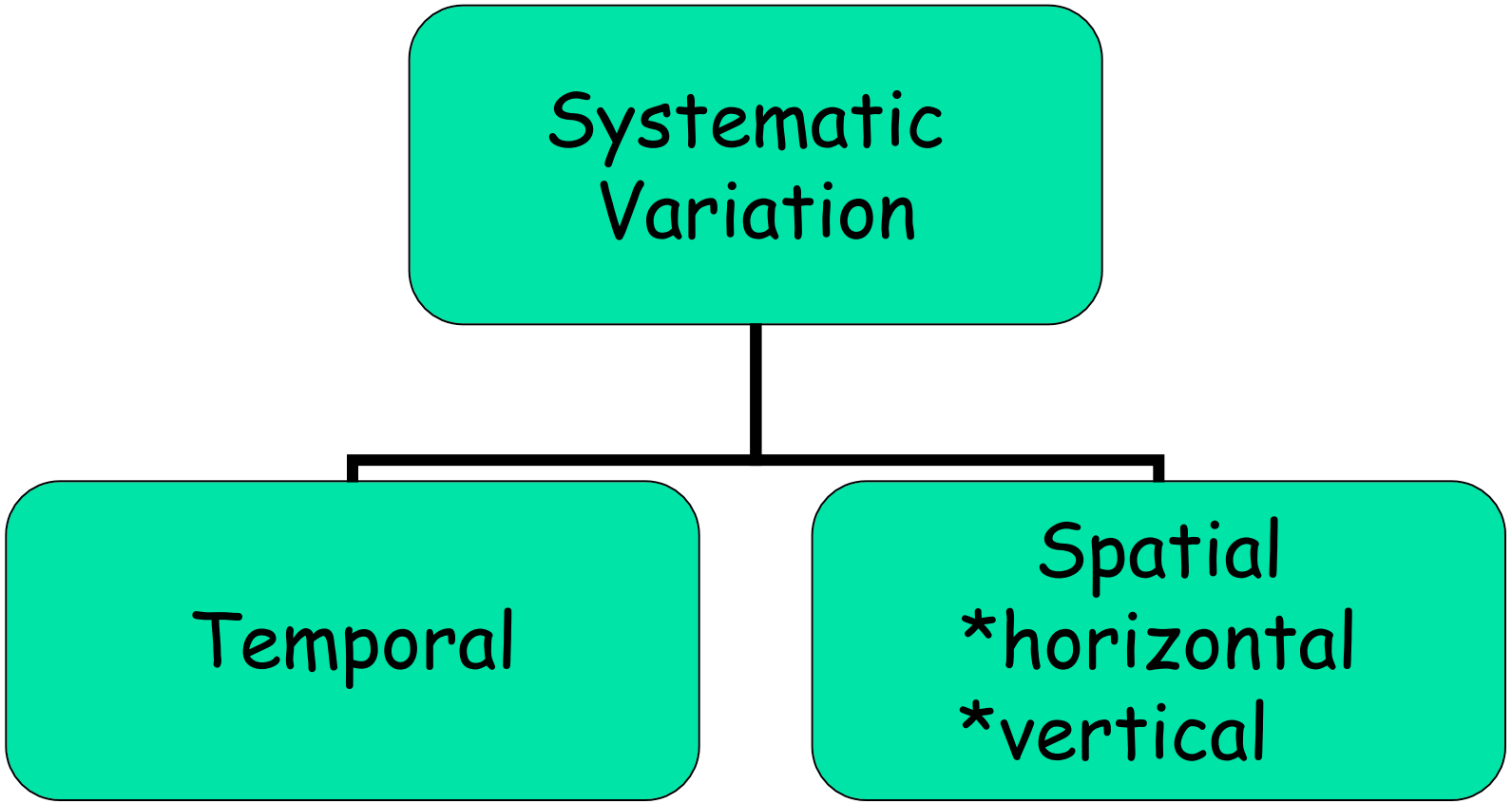
# The systematic or modeled part also has two components

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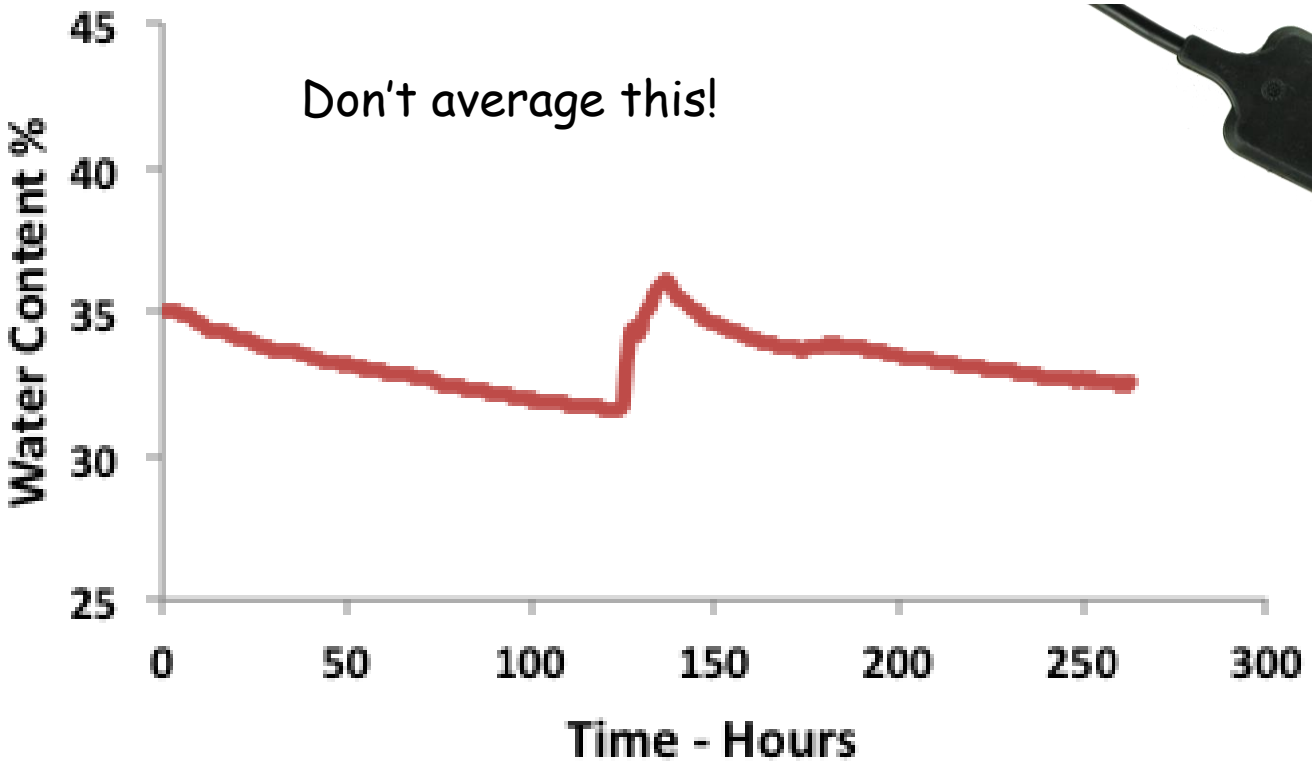
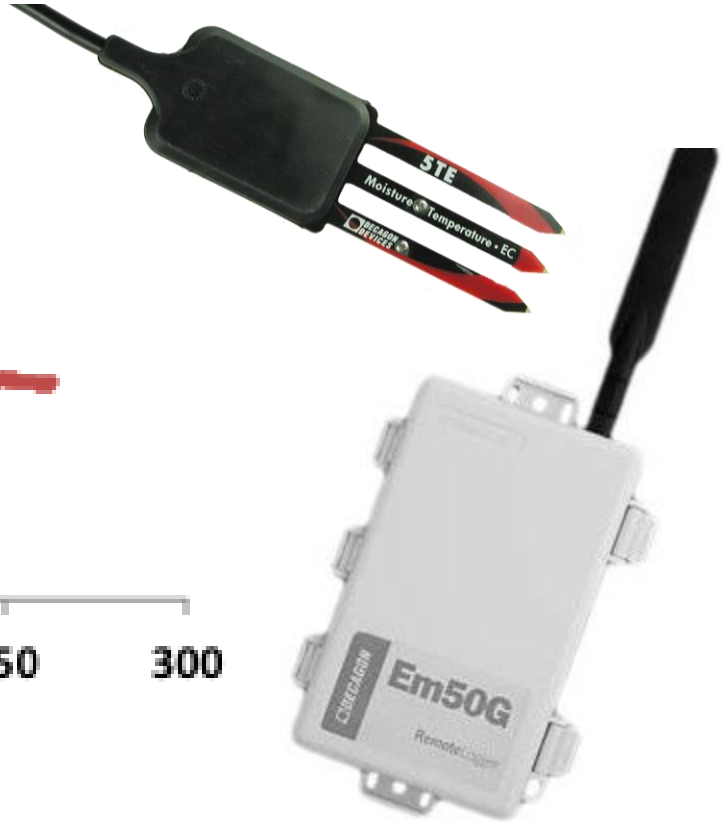
# Temporal Variation - Drydown/wetup of a sensor

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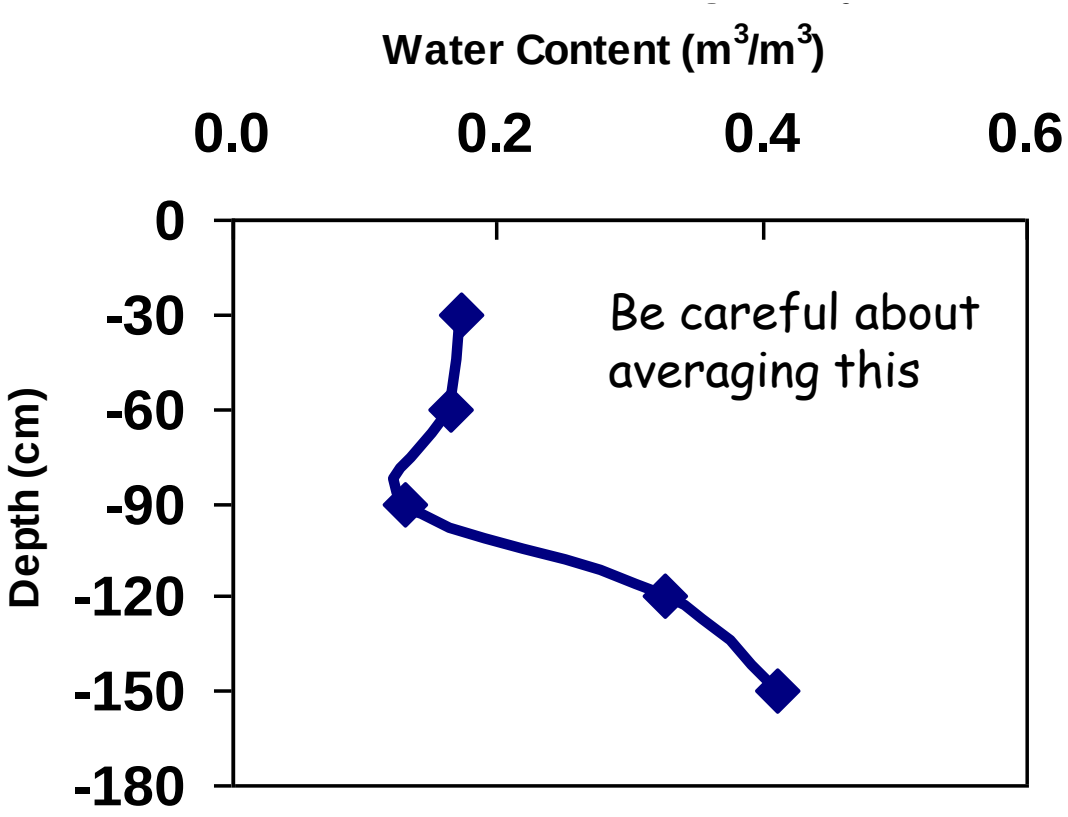
# Water content variation with depth in a wheat field

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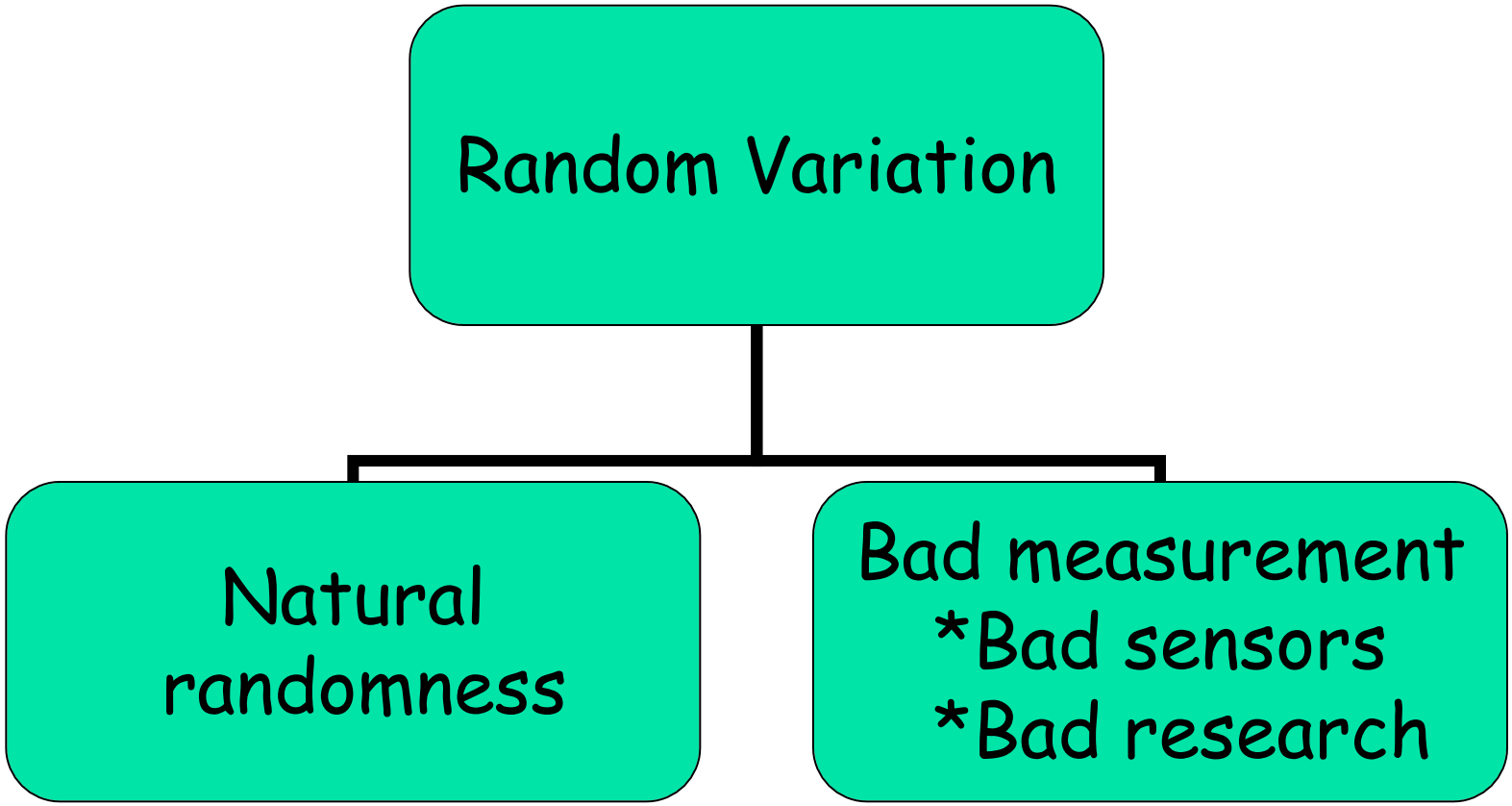
# Random variation also has two components

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# Points to remember

- Averaging is a slippery slope – don't throw the baby out with the bathwater
- Average over randomness – model and measure the rest
- Don't create randomness through sloppy experimental methods

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# Soccer field data, again: spatial distribution of variance

- How do I sample to properly represent the field?
- Does my sampling scheme affect the variance (or standard deviation) I get?
- Are samples from the same spot more similar than more widely spaced samples?

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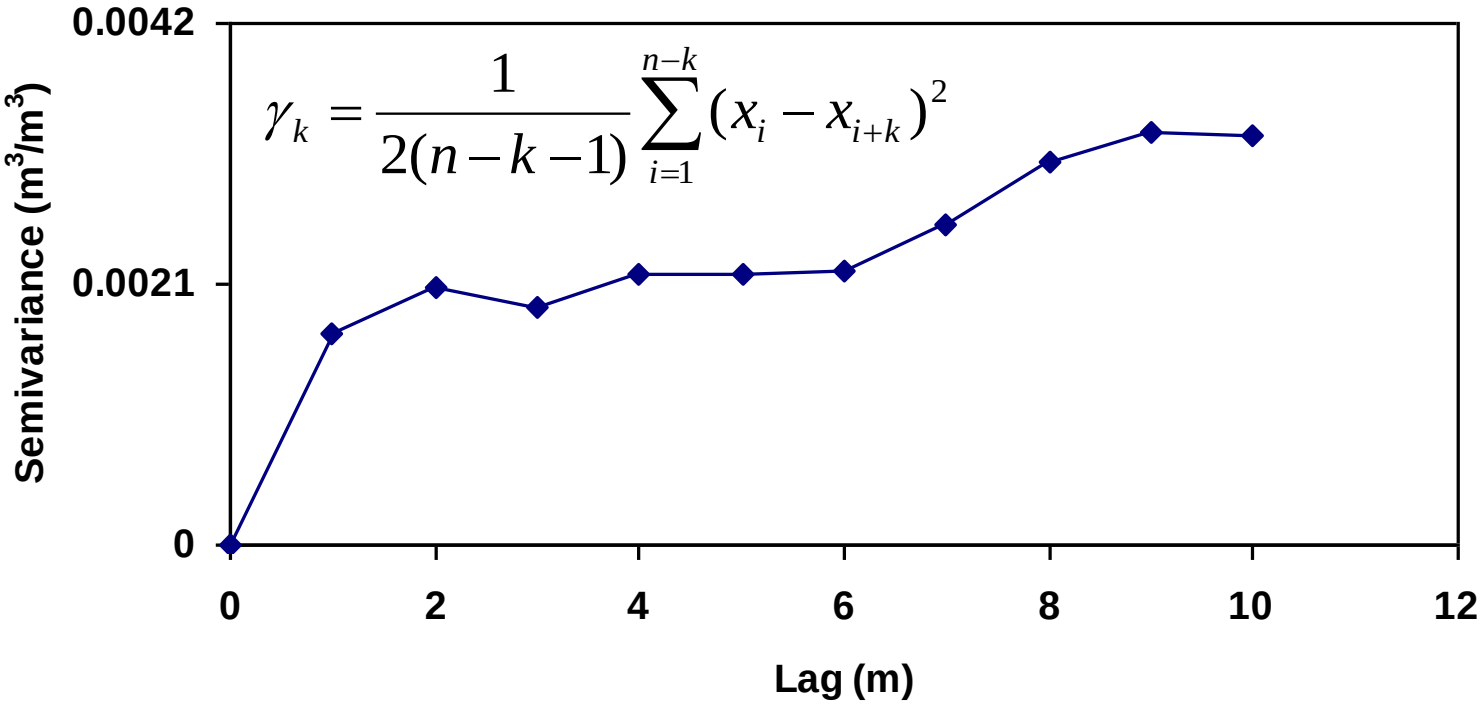
# Soccer field semivariogram

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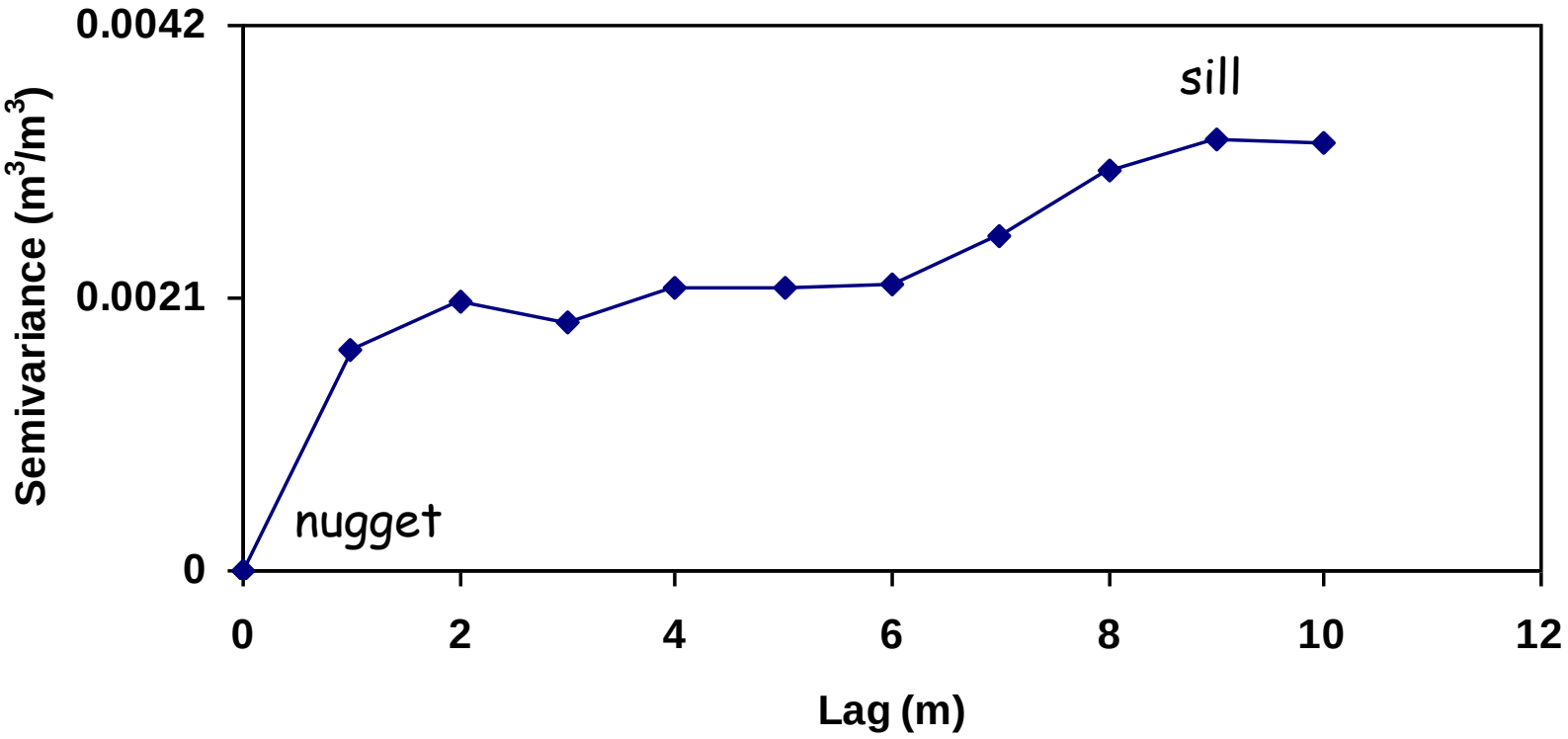
# Soccer field semivariogram

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# Why two probes in the same field might read differently

- Electronic or calibration problems
- Installation problems
- Water content does, in fact, vary in space and time – why?

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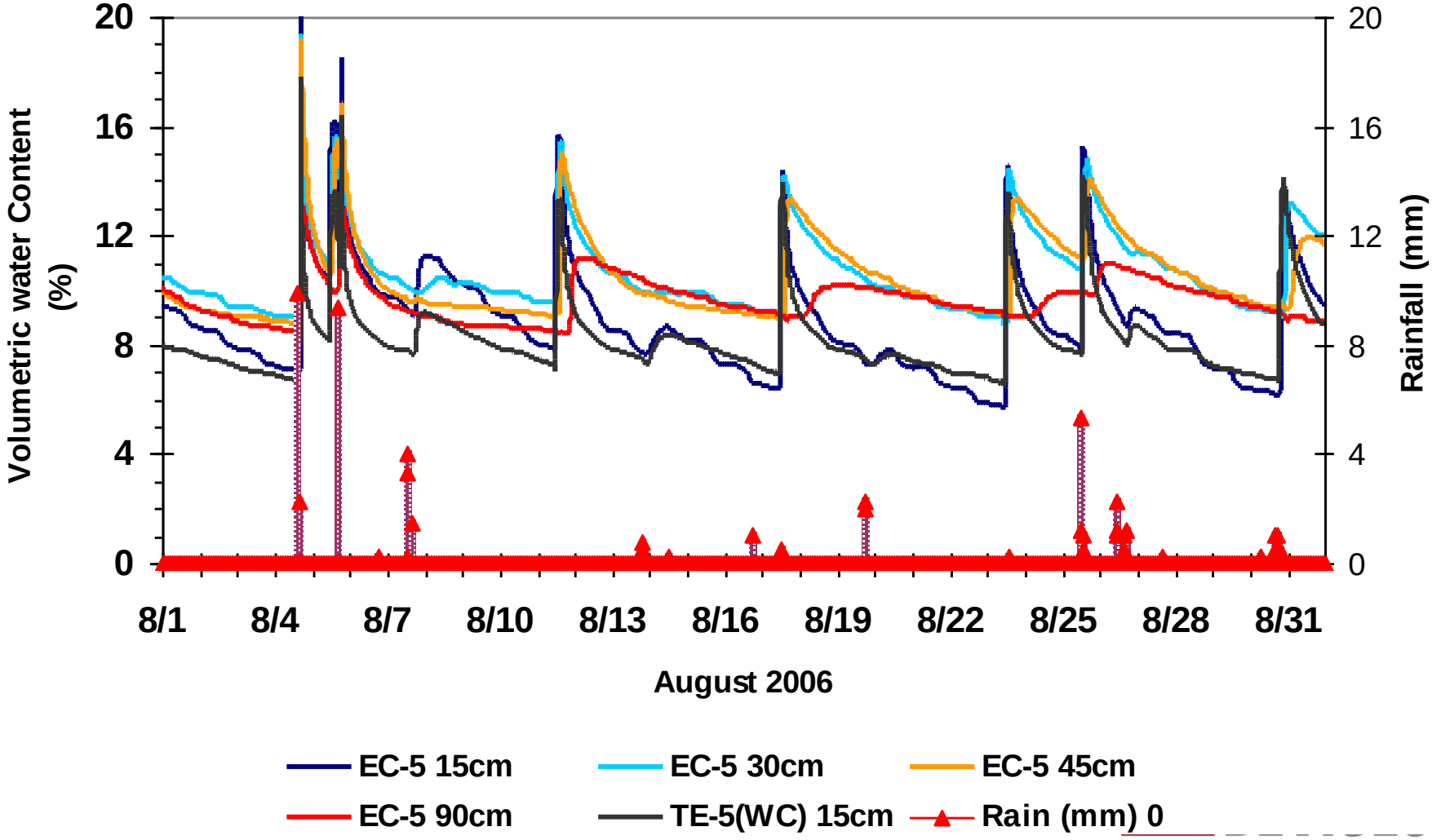
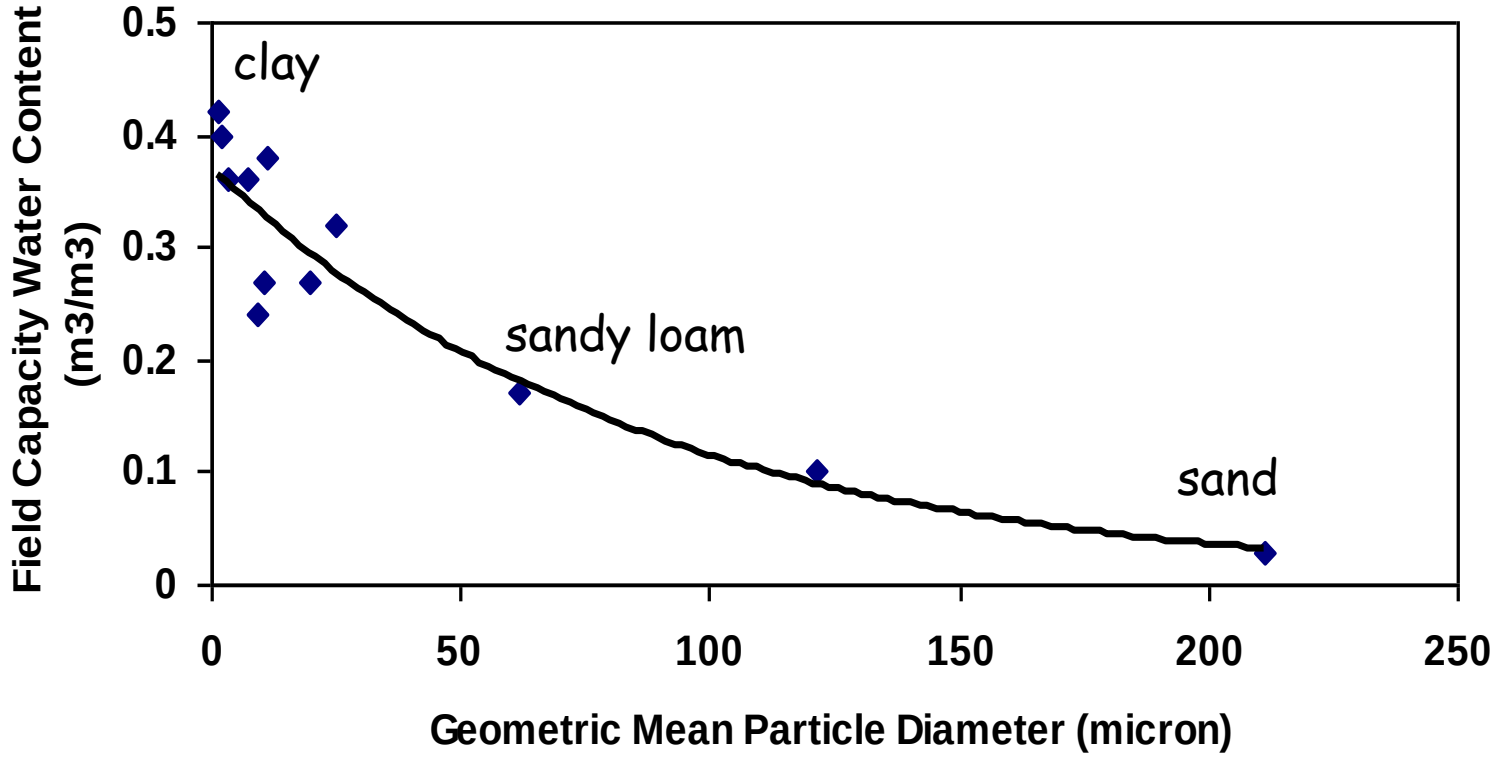
# Field Capacity:The water content of a soil profile 2-3 days after a heavy rain or irrigation



# Field capacity water content depends on soil texture

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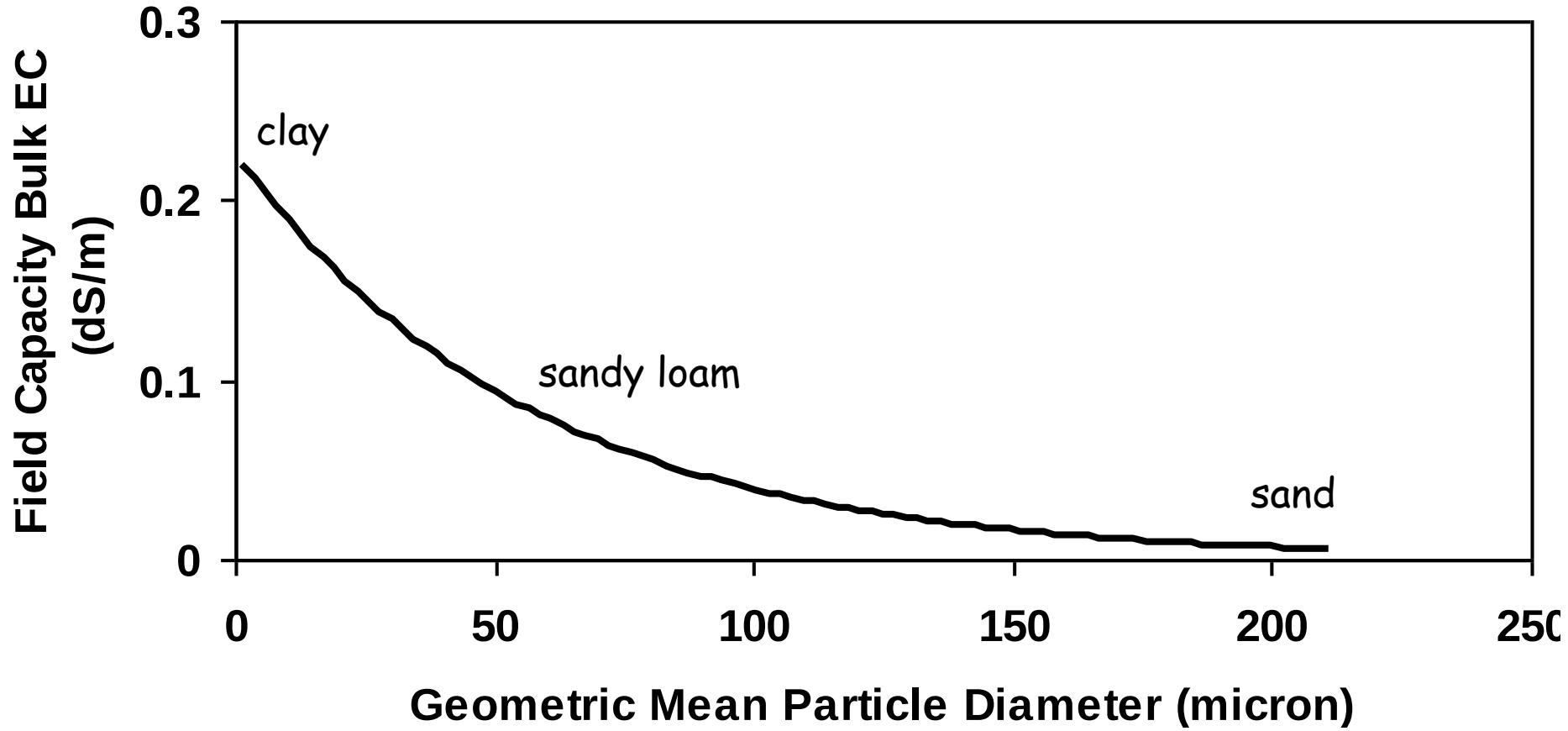
# Soil moisture variation can give information about texture

- Texture is a source of variation when soil is at field capacity or permanent wilt
- Texture is also a source of variation if it reduces permeability

# Bulk EC can also be a covariate

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# EC Maps Can Show Texture Distributions

- Field capacity water content is determined by texture
- Relative bulk electrical conductivity is determined by water content
- The $EC_b$ map therefore shows water content and texture distributions

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# Points to remember

- Soil moisture variation is typically not random. More closely spaced points have lower variance than more widely spaced ones
- If water content is properly measured, variations can give information about soil properties

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# More points to remember

- Texture and field capacity water content are correlated

- Texture and bulk EC are correlated because bulk EC and water content are correlated. Bulk EC maps can be texture maps if they are made when the soil is at field capacity.

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